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Review article

Epidemiological surveillance in the ICU: Certainties and uncertainties

Vigilancia epidemiológica en UCI: certezas e incertidumbres

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ABSTRACT

Surveillance for colonization by multidrug-resistant microorganisms (MDR) in patients admitted to intensive care units (ICUs) can be passive or active. Active surveillance (nasal/rectal sampling on admission and weekly) allows for early isolation of asymptomatic carriers, combined with universal or targeted decolonisation. This limits dissemination more than passive surveillance. Knowing which microorganisms to monitor, how often, and the various methodologies are some of the aspects emphasized in this review.

RESUMEN

La vigilancia de la colonización por microorganismos multirresistentes (MMR) en pacientes ingresados en unidades de cuidados intensivos (UCI) puede ser pasiva o activa. La vigilancia activa (muestreo nasal/rectal al ingreso y semanal) permite aislamiento precoz de portadores asintomáticos, combinado con descolonización universal o dirigida. Esto limita la diseminación más que la vigilancia pasiva. Conocer cúales son los microorganismos a vigilar, con qué frecuencia y las variadas metodologías, son algunos aspectos que se enfatizan en esta revisión.

Introduction

Surveillance of colonization by multidrug-resistant microorganisms (MDROs) in patients admitted to intensive care units (ICUs) can be passive or active. Passive surveillance is based on the incidental detection of MDROs from prior positive clinical cultures, with infection control measures implemented only in those cases. This approach has major limitations, including underreporting, lack of standardization, and poor timeliness of data, which may lead to an underestimation of the true colonization rates.

In contrast, active surveillance involves the proactive identification of at-risk patients through the systematic collection of surveillance cultures, which requires personnel specialized in infection control and microbiology, as well as adequate coordination among the different hospital departments. Surveillance cultures, usually obtained from nasal, pharyngeal, skin and/or rectal swabs, should be performed at a frequency tailored to local colonization and infection rates and to the hospital's epidemiological context.[1] In this regard, the European Society of Clinical Microbiology and Infectious Diseases (ESCMID) strongly recommends the use of surveillance cultures as a key strategy for controlling carbapenem-resistant Enterobacterales.[2]

Definition of MDROs under surveillance in the intensive care unit

In the context of nosocomial infections, the ESKAPE group of pathogens represents a persistent threat. This group includes *Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and *Enterobacter* spp., so named for their ability to "escape" the action of antimicrobials, which markedly limits the available therapeutic options.[3]

Several public health agencies recommend surveillance of multidrug-resistant organisms (MDROs). The Public Health Agency of Canada prioritizes *Candida auris*, *Clostridioides difficile*, carbapenemase-producing organisms, methicillin-resistant and methicillin-susceptible *S. aureus* bloodstream infections, and vancomycin-resistant *Enterococcus*.[4] Likewise, in its report updated in November 2022, the CDC classifies MDROs into four priority tiers (Tier 1–4) according to the healthcare setting, and recommends surveillance cultures for methicillin-resistant *S. aureus*, vancomycin-resistant enterococci, carbapenemase-producing gram-negative bacilli—including multidrug-resistant *Pseudomonas* and *Acinetobacter*—and *C. auris*.[5] Concordant recommendations have been issued by SHEA, IDSA, APIC, AHA, and The Joint Commission.[6]

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In its most recent update, the World Health Organization (WHO) classifies carbapenem-resistant *Acinetobacter*, carbapenem-resistant and third-generation cephalosporin-resistant Enterobacterales as multidrug-resistant pathogens of critical priority, and carbapenem-resistant *P. aeruginosa*, methicillin-resistant *S. aureus*, and vancomycin-resistant *E. faecium* as high-priority pathogens.[7] The WHO issues a strong recommendation, albeit based on low-quality evidence (AIII), for performing surveillance cultures targeting these multidrug-resistant organisms (MDROs), both in asymptomatic patients and in the context of outbreaks or in their absence.[8]

The high attributable mortality associated with these pathogens and the increased risk of bloodstream infection in colonized patients, particularly with carbapenem-resistant Enterobacterales such as *K. pneumoniae*, further support the need for close follow-up using surveillance cultures.[9,10] Likewise, recommendations on selective digestive decontamination provide indirect criteria for selecting the MDROs to be monitored and for assessing the effectiveness of this strategy.[11]

With regard to specific MDROs, the prevalence of methicillin-resistant *S. aureus* (MRSA) in European ICUs ranges from 1 to 7%, with a mean of 3.9%, and an overall acquisition rate of 2.5 per 1000 at-risk patient-days, with wide variability among units.[12] The risk of infection and its severity justify the systematic use of surveillance cultures and molecular screening for MRSA in ICUs. There is consistent evidence supporting the effectiveness of surveillance cultures based on nasal swabs and skin swabs in adult and neonatal ICUs.[13,14] In outbreak settings, MRSA colonization pressure is independently associated with its acquisition in neonatal ICUs,[15] and the combination of surveillance cultures with isolation measures and mupirocin-based decolonization contributes to reducing MRSA infections in this setting.[16,17]

Regarding vancomycin-resistant enterococci (VRE), a prospective ICU study using serial rectal swabs at admission, weekly, and at discharge identified a colonization prevalence of 5.8% (101/1730 patients). Among colonized patients, 11.8% developed VRE infection, with urinary and respiratory infections being the most frequent, followed by surgical site and catheter-related infections. *E. faecium* was the most commonly isolated species in both colonized and infected patients. Notably, two-thirds of colonized patients became culture-negative during their ICU stay, whereas longer ICU length of stay and prior renal replacement therapy were associated with an increased risk of progression from colonization to infection.[18]

With respect to colonization by multidrug-resistant gram-negative bacilli (MDR-GNB) and its clinical impact, a systematic review including studies published between 1995 and 2022 reported a pooled cumulative incidence of infection of 14% in patients colonized with MDR-GNB and 8% in those colonized with VRE, with a median follow-up of 30 days.[19] Recent studies also confirm the high prevalence of β-lactamase-producing organisms—including ESBLs, AmpC, and metallo-β-lactamases—as causative agents of ventilator-associated pneumonia, which underscores the need for continuous surveillance programs, early detection of resistance, and comprehensive infection control strategies in ICUs.[20]

Consistently, Harris et al. showed that patients colonized with *P. aeruginosa* have a significantly higher risk of subsequently developing positive clinical cultures compared with non-colonized patients, highlighting the predictive value of colonization in this setting.[21]

A. baumannii is an important cause of ventilator-associated pneumonia (VAP). A meta-analysis by Panahi et al. evaluated the prevalence of multidrug-resistant (MDR) *A. baumannii* in patients with VAP and found high resistance rates: 71% for MDR strains, 73% for extensively drug-resistant (XDR) strains, and 40% for pandrug-resistant (PDR) strains.[22] Another recent meta-analysis confirmed that invasive infection due to carbapenem-resistant *A. baumannii* (CRAB) is significantly more frequent in colonized patients, with a markedly higher risk of bacteremia and a high negative predictive value for invasive infection in non-colonized patients.[23] However, no significant differences were observed in the incidence of VAP, length of hospital stay, or mortality, and the evidence supporting the clinical benefit of active CRAB screening remains limited.

Surveillance of colistin-resistant *Acinetobacter* is a priority, alongside strict implementation of isolation and hygiene measures. Nevertheless, unlike the situation for MRSA and VRE, routine use of gloves and gowns has not been shown to reduce acquisition of multidrug-resistant gram-negative bacilli, including carbapenem-resistant Enterobacterales and *Acinetobacter*, carbapenem-resistant *P. aeruginosa*, and ESBL producers.[24]

Stenotrophomonas maltophilia accounts for less than 3% of healthcare-associated infections overall, but this proportion doubles in the context of VAP, where it ranks as the third most frequently isolated non-fermenting gram-negative bacillus. Traditionally regarded as a transient colonizer, there is growing evidence supporting its role as a true pathogen causing pneumonia and bloodstream infection in critically ill patients, even in the absence of overt immunosuppression. It has been associated with high 28-day mortality and a broad pattern of intrinsic resistance, together with a progressive increase in resistance to first-line agents such as trimethoprim-sulfamethoxazole and tigecycline. In this context, some ICUs have implemented targeted screening strategies to prevent severe infections caused by this microorganism.[25]

Recent outbreaks of *C. auris* have highlighted its importance as an emerging pathogen that demands strict strategies for surveillance, isolation, and contact precautions for both patients and healthcare personnel. In this setting, follow-up cultures in colonized patients are essential, as are environmental cultures—including surfaces and reusable devices—to achieve effective control of transmission.[26] In parallel, the emergence of azole-resistant *Candida parapsilosis* has been described as a new threat, associated with outbreaks in neonatal ICUs, with frequencies exceeding those of *Candida albicans* and *Candida glabrata*.[27]

Regarding *C. difficile*, colonization at ICU admission, determined by perianal swab, reaches rates close to 9%. However, universal use of gloves and gowns for contact with all patients has not been shown to reduce colonization rates, as demonstrated in a multicenter randomized clinical trial conducted in medical and surgical ICUs in the United States.[28]

How often should active surveillance cultures be performed?

Surveillance cultures (SCs) should be obtained as early as possible after hospital admission or exposure to risk and processed and reported promptly—ideally within 48 hours—to avoid delays in identifying colonization by carbapenem-resistant Enterobacterales (CRE). The available evidence does not allow a single optimal frequency of SCs after ICU admission to be defined, due to the heterogeneity and limitations of published studies. Nevertheless, several studies propose periodic SCs, with a weekly or twice-weekly schedule following the initial admission screen.[29–31]

In this context, one comparative study showed that a strategy based on SCs at admission and discharge identifies 91% of prevalent colonizations by multidrug-resistant organisms (MDROs) and 63% of those acquired during the ICU stay, when compared with continuous SCs[32] (Fig. 1). However, this approach may underestimate the acquisition of new MDRO colonizations during hospitalization.

Weekly surveillance cultures represent a pragmatic compromise that supports high, sustained adherence. In neonatal ICUs, this strategy allows characterization of the dynamic epidemiology of colonization by multidrug-resistant gram-negative bacilli (MDR-GNB), early detection of importation and spread of new clones, timely implementation of contact precautions, and assessment of risk factors for colonization.[33] It also helps optimize antimicrobial use, which is particularly relevant in neonates, where empirical treatment often has to be started in the absence of clinical culture results, thereby reinforcing the value of active surveillance programs.[33]

For analyzing the acquisition of MDROs, SCs should be used whenever possible, since clinical cultures are not an adequate substitute. In

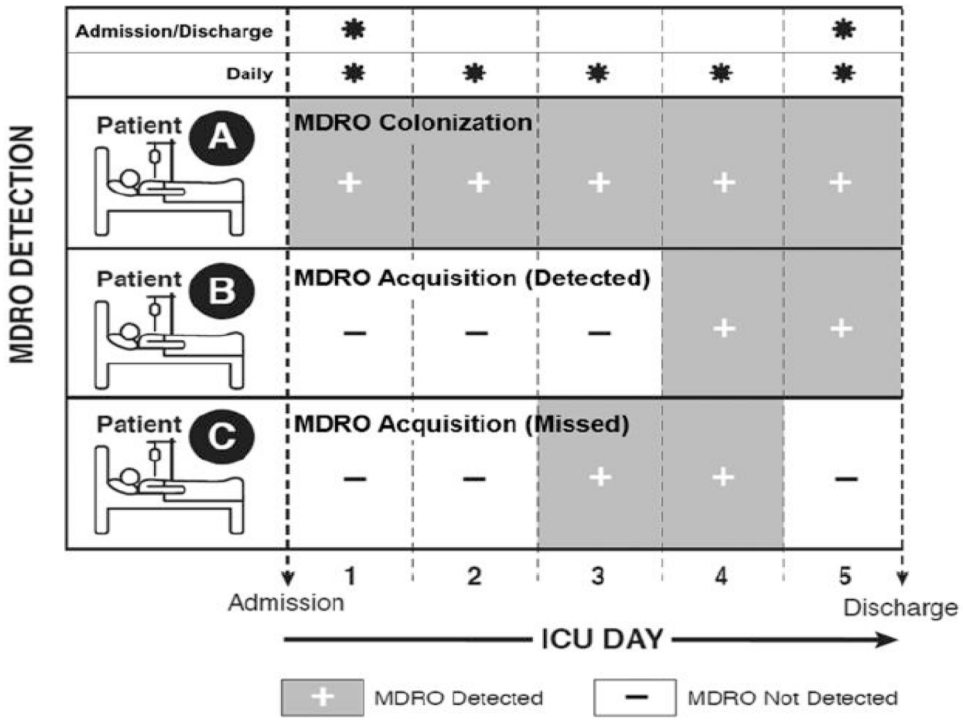

Fig. 1. Diagram of the surveillance culture detection strategy (modified from Ref. 32). This figure illustrates a comparative strategy for detecting multidrug-resistant organism (MDRO) colonization in the ICU, showing that cultures at admission and discharge identify 91% of prevalent cases and 63% of incident cases, relative to continuous surveillance. It highlights the trade-offs between resource-intensive weekly screening and pragmatic admission/discharge protocols for optimizing MDRO detection in clinical practice.

the study by Sansom et al., only 7% of patients colonized by MDROs were identified through clinical cultures.[6] Although a correlation has been described between active surveillance and MRSA incidence rates based on clinical cultures in medical and surgical ICUs, this relationship is not observed for vancomycin-resistant enterococci (VRE). Indeed, VRE incidence density rates based on SCs are two- to fourfold higher than those derived from clinical cultures, so evaluation criteria must cover the full continuum from colonization to infection, recognizing that clinical and SC-based indicators are not interchangeable.[34]

Sampling frequency is also linked to the duration of MDRO colonization. A retrospective study of patients colonized by carbapenemase-producing Enterobacterales (CPE) found that approximately one-third of patients cleared colonization, with a mean time to clearance of 80 days. Immunosuppression, mechanical ventilation, and carbapenem therapy were associated with a lower likelihood of clearance, whereas colonization at multiple body sites was associated with a higher probability of decolonization.[35] Complementarily, a prospective study comparing clearance of NDM-1- versus KPC-producing CPE showed a significantly higher rate of decolonization among NDM-1 carriers, while KPC carriers remained colonized during admission and on subsequent readmissions, suggesting relevant differences in colonization persistence according to carbapenemase type.[36]

In low-prevalence settings, some authors propose a targeted surveillance approach (Fig. 2) based on risk factors and clinical characteristics, with intensified surveillance during outbreaks or endemic situations. This model may be suitable for many adult and neonatal ICUs, as it optimizes resource use, reduces costs, and minimizes potential undesired effects of continuous surveillance, without compromising patient safety.[37]

In highly endemic MRSA settings, surveillance of dual intestinal colonization by MRSA and VRE using rectal swabs at admission and weekly is recommended in order to anticipate the emergence of vancomycin-resistant *S. aureus*.[38] Moreover, a study of burn patients admitted to ICUs showed that discontinuation of MRSA SCs was associated with increased hospital MRSA bloodstream infection rates, underscoring the importance of maintaining active surveillance programs.[39]

Which microorganisms should be routinely monitored in active surveillance cultures? Role of molecular techniques?

A 2022 systematic review confirms that surveillance cultures (SCs) are the most commonly used strategy for infection control in ICUs, featured in 29 of 30 analyzed studies.[40] However, the evidence for SCs targeting carbapenem-resistant *A. baumannii* (CRAB) and carbapenem-resistant *P. aeruginosa* (CRPA) is insufficient to support universal recommendations, with their utility depending on the clinical setting, epidemiological stage, and colonization sites.[29,30,41,42]

The value of SCs is enhanced by improved techniques, such as pre-enrichment and molecular methods (PCR, PFGE, MLST), which enable genotypic characterization of strains carrying carbapenemase-resistance genes in endemic settings, where polyclonality may exist (KPC + NDM, NDM + OXA).[43–45] For instance, whole-genome sequencing of carbapenem- and colistin-resistant *K. pneumoniae* strains demonstrated clonality and patient-to-patient transmission, highlighting the need for coordination between microbiologists and infection control teams to implement intensive SCs with genetic typing.[46]

Molecular typing of carbapenemase-producing Enterobacterales and *Acinetobacter* strains has confirmed that intrahospital transmission can exceed external introductions, underscoring the need for active surveillance and continuous monitoring within the ICU, with early detection of genes such as blaNDM, blaKPC, blaVIM, blaIMP-1, and blaOXA-48.[43,47–50] Quasi-experimental programs have shown that implementing weekly SCs combined with infection control measures can significantly reduce infections due to carbapenem-resistant *K. pneumoniae* and *P. aeruginosa*, although results for *A. baumannii* are variable and depend on complementary measures such as glove and gown use and daily chlorhexidine bathing.[51,52]

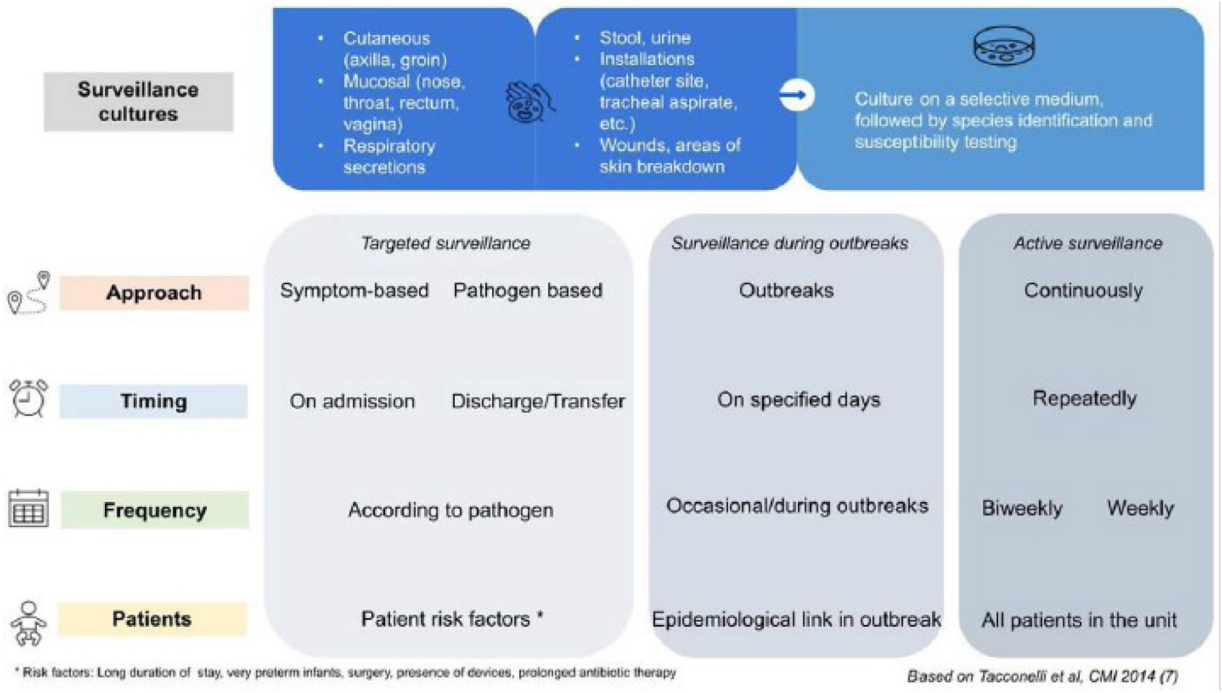

Fig. 2. Diagram of three surveillance culture strategies and their characteristics (taken from Ref. 37). This figure outlines three surveillance culture (SC) approaches—targeted, during outbreaks and active surveillance—contrasting their timing, frequency and suitability across low- vs. high-prevalence ICU settings.

In contrast, contact precautions for ESBL-producing Enterobacterales in endemic areas do not consistently yield epidemiological or clinical benefits, and there is insufficient evidence to recommend systematic screening in the absence of outbreaks.[53,54] The costs associated with SCs and contact isolation are substantial: annual laboratory costs are estimated at $19,000 for VRE, and $718 per ICU patient, so in low-endemicity areas (<5% isolation rate and <1% infection rate), SCs should be individualized based on additional criteria.[55] In this context, ICUs with low ESBL endemicity and good adherence to isolation have shown that discontinuing SCs does not affect infection incidence or clinical outcomes.[56]

What impact do surveillance cultures have on antibiotic use and infection control?

Surveillance cultures (SCs) are included among ICU quality indicators for appropriate antibiotic use. A retrospective study by Court et al. showed that, in high-risk neutropenic patients, performing weekly pharyngeal and rectal SCs from one week before chemotherapy until neutrophil recovery can reduce carbapenem use by decreasing inappropriate empirical treatment of multidrug-resistant gram-negative bacilli (MDR-GNB) bacteremias, without adverse clinical impact.[57] SCs have also demonstrated utility in reducing multidrug-resistant *Acinetobacter* outbreaks without restricting carbapenems[52] and in evaluating the effectiveness of isolation, prevention, and decolonization measures, including selective digestive or oral decontamination.[58–62]

However, the available evidence is heterogeneous according to country, ICU type, and MDRO studied. For example, in neonatal ICUs, SCs are effective in only one-third of cases, while methicillin-resistant *S. aureus* (MRSA) remains the leading cause of outbreaks in Japanese ICUs despite reporting all SC isolates.[63–65] The evidence favors SC use particularly for carbapenem-resistant gram-negative bacteria, but its quality is poor and does not allow robust assessment of clinically relevant outcomes such as infection, length of stay, or mortality.[42]

Routine use of SCs for extended-spectrum β-lactamase (ESBL)-producing Enterobacterales in endemic settings is controversial. For instance, Kim et al. studied 281 ICU patients using perirectal swabs and molecular typing (PCR and PFGE) and found a 6.4% (18/281) colonization rate by ESBL *K. pneumoniae*, with all isolates carrying CTX-M-15 and a clustered clonal pattern, suggesting cross-transmission without a documented outbreak.[66] Therefore, the value of SCs for controlling CRE outside outbreaks is questionable, as is their utility in predicting patients at risk of ESBL infection and guiding empirical carbapenem use.[40,54,66]

What types of samples should be used in active surveillance cultures?

With respect to the yield of different surveillance cultures (SCs) in ICUs according to MDROs, one study[41] reported the following results (Table 1): 24.4% of patients were colonized/infected with MDROs at admission. Nasal, pharyngeal, and rectal swabs were the most effective samples for recovering MRSA, MDR-AB, and Kp-ESBL and/or carbapenemase producers, respectively. Combining two samples improves MDRO detection, except for *K. pneumoniae* ESBL and/or carbapenemase producers, whereas skin swabs show limited utility. ESBL-producing Enterobacterales were the most prevalent MDROs at admission, and multidrug-resistant *A. baumannii* was the most frequent one acquired during hospitalization.[41] Stool, rectal, or perianal swabs (especially in neutropenic patients) are the most accurate methods for detecting CRE, although rectal swabs are the most commonly used option in clinical practice for practicality. The number of cultures should not be limited, as additional samples increase the detection rate[1,29,30] (Table 2).

A recent study published in *Sci Report* (2023) assessed the correlation between salivary cultures and blood cultures for *Klebsiella* in critically ill patients, finding a significant correlation and predictive values of 25–35%, superior to those obtained with tracheal aspirates, although further studies are needed to confirm these findings.[67]

What is the value of active surveillance cultures for predicting infection risk?

The effectiveness of surveillance cultures (SCs) in predicting the causative agent of subsequent infections and guiding empirical treatment is heterogeneous. Tracheal aspirates (TAs) have been extensively

Table 1
Yield of different types of surveillance cultures according to MDROs (Ref. 41).

Sample type	MRSA (%)	MDR-AB (%)	ESBL/Carbapenemase-producing *K. pneumoniae* (%)
Nasal swab	79	73	37
Pharyngeal swab	48	80	58
Rectal swab	17	74	95
Cutaneous swab	9	52	42
Nasal + Pharyngeal	90	83	62
Nasal + Rectal	76	92	95
Pharyngeal + Rectal	55	95	98

This table summarizes the performance of surveillance cultures from a key ICU study, where 24.4% of patients were colonized/infected with MDROs at admission. Nasal swabs excelled for MRSA detection, pharyngeal for MDR *Acinetobacter baumannii*, and rectal swabs for ESBL/carbapenemase-producing *Klebsiella pneumoniae*. Combining samples boosted overall sensitivity, except for *K. pneumoniae* where rectal swabs alone were optimal. ESBL Enterobacterales were most prevalent at admission, while MDR *A. baumannii* predominated among acquired cases.

Table 2
List of MDROs and types of active surveillance cultures (Ref. 1. Biswal M et al., 2020).

MDRO	Recommended surveillance culture sites
MRSA	Nasal swab
VRE	Feces, rectal/perianal swab
CRE	Rectal swab
CRAB	Axilla/groin swab, rectal swab
CRPA	Rectal swab, respiratory if ventilated
ESBL Enterobacterales	Rectal swab
Candida auris	Axilla/groin swab, feces

This table from Biswal et al. (2020) summarizes standard sampling sites for active surveillance of priority MDROs in ICU settings, emphasizing high-yield anatomical niches for each pathogen to maximize detection while minimizing unnecessary sampling. Rectal swabs are versatile for enteric organisms, while nasal/axillary sites target staphylococci and yeasts.

evaluated in ventilator-associated pneumonia (VAP), showing 72–83% microbiological concordance if obtained within 48–72 h before diagnosis, with 78% sensitivity, 96% specificity, and 95% negative predictive value (NPV), particularly for *Pseudomonas* and multidrug-resistant Enterobacterales.[42] However, studies have methodological limitations and inconsistent results regarding the utility of TAs for guiding empirical therapy or antibiotic de-escalation, with no demonstrated impact on mortality or clinical prognosis.[68] Systematic monitoring may reduce unnecessary broad-spectrum antibiotic use, as a recent negative culture indicates low likelihood of MDRO infection.[69]

Subglottic cultures show high correlation with TAs and bronchoalveolar lavage, with 81% overall accuracy and acceptable predictive values, suggesting they could replace TAs in predicting VAP causative agents.[70] In patients with high ESBL Enterobacterales burden, prior colonization, or late-onset VAP, a negative rectal surveillance culture reduces the risk of ESBL VAP to $<1\%$, and molecular methods enable results in a few hours.[71]

In sepsis and ICU settings, SC positivity combined with clinical factors (procalcitonin, SIRS, qSOFA) helps identify patients at higher risk of developing infection by the same microorganism detected in the swab.[72] Perianal SC-detected MDR *Acinetobacter* colonization is associated with greater severity and mortality.[73]

In surgical ICUs, a negative admission nasal swab rules out MRSA infection with high probability, avoiding unnecessary empirical treatment, while positive colonization predicts higher infection risk.[74] Studies in burn patients show that $>60\%$ of those with positive colonization develop secondary infection, and no patient with a negative swab developed MRSA infection.[75] Similarly, rectal MDRO colonization is an independent risk factor for surgical site infections, although it does not prove direct causality (OR 3.95; 95% CI: 2.79–5.60).[76]

Overall, SCs enable identification of at-risk patients and guide therapeutic decisions, especially in units with high MDRO endemicity, although evidence on direct clinical impact, antibiotic de-escalation, and mortality prevention remains limited.

Authorship

The author declares the accuracy of the data as part of their review work, and the tables included in the text are properly referenced and explained.

Ethical considerations

This study was conducted in accordance with the journal's editorial guidelines for review, update, and reformulation articles, based on a literature search of the available evidence on the topic.

Informed consent

Not applicable to this review article.

Use of artificial intelligence

The English version of the manuscript was produced using DeepL online translator and style was reviewed by ChatGPT 5.0.

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Conflict of interest

Dr. Juan M. García-Lechuz declares no conflicts of interest.

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